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Evaluating the Potential of Fermented Leguminous Plant Leaves as a Fertilizer for Rice *(Oryza sativa)* Production

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Abstract. Synthetic fertilizers improved rice yield, but they were expensive and reduced soil health. Fermented leguminous plant leaves (FLPL) were natural fertilizers that had a lot of nutrients that plants needed to grow and develop because they were locally available and economical to farmers. This study investigated the effects of fermented leguminous plant leaves as fertilizer for rice. The four treatments were arranged in a Randomized Complete Block Design and replicated three times. Plant height, tillers, grain weight, and economic returns were collected and analyzed using Analysis of Variance (ANOVA). The results showed that the control group that received synthetic fertilizers had significantly ($P>0.05$) taller rice plants compared to the treatment groups. However, among the fermented leguminous leaves, rice plants that received Madre de cacao showed the highest plant height due to its high phosphorus content. The study also found no significant differences ($P<0.05$) in the number of tillers between the treatments, indicating that fermented leguminous leaves can provide the necessary nutrients for crop growth. It was concluded that fermented leguminous leaves can be used as fertilizer to promote eco-friendly rice farming practices. Madre de cacao leaves were recommended as organic fertilizer for rice for at least three months to enhance plant height and overall plant growth. The potential of FLPL, especially from madre de cacao, as an economical alternative to synthetic fertilizers is a breakthrough in rice production. The results demonstrated the potential benefits of using Madre de Cacao leaves as fertilizer to promote eco-friendly rice farming.

Keywords: Acacia; Fermented leguminous leaves; Ipil-Ipil; Madre de cacao; Organic fertilizer

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INTRODUCTION

The results of a focus group discussion conducted by the Dr. Emilio B. Espinosa Sr. Memorial State College of Agriculture and Technology, Cawayan Campus Extension Services, and Linkages Unit in Barangay Itombato in 2020 showed that the farmers in the area have a preference for synthetic fertilizers over organic ones. This is because organic fertilizers have low nutrient content and a slow processing time, as reported in a study by Kim et al. (2019). Nevertheless, the use of synthetic fertilizers can be a financial burden for small-scale farmers as they tend to be more expensive (Nyamangara et al., 2020). Despite efforts to increase rice production in the Philippines, including the use of fertilizers, the country remains dependent on imports, as low yields persist (Food and Agriculture Organization, 2021).

To address this challenge, researchers at the DEBESMSCAT-Cawayan Campus have explored the potential of using leguminous leaves as a substitute for synthetic fertilizer. Setyaningsih et al. (2017) found that the use of fermented leguminous plant leaves (FLPL) as a fertilizer in rice production increased the income of smallholder farmers in Indonesia, as it is a low-cost and locally available fertilizer source that can be produced by farmers themselves. Studies have shown that FLPL has a positive impact on the growth and yield of rice plants, as well as the soil's physical and chemical properties, including an increase in organic matter and nitrogen content (Kim et al., 2019; Li et al., 2020; De Rosa et al., 2022). Furthermore, the use of FLPL as a fertilizer has been found to reduce methane emissions compared to traditional chemical fertilizers (Zhang et al., 2018), and improve soil properties such as water-holding capacity, cation exchange capacity, and microbial biomass (Zhang et al., 2016; Cao et al., 2018; Liu et al., 2017).

The nitrogen, phosphorus, and potassium content of FLPL varies based on the species and conditions under which they were produced. Paul et al. (2015) reported that per ton of dry ipil-ipil leaves contain 4.3% nitrogen (N), 0.4% phosphorus (P), and 2.7% potassium (K), while Natividad (2011) found that fermented madre de cacao leaves had 3.8% N, 1.8% P, and 2.8% K. Study of Almahy and Nazir (2011) found that acacia leaves contain 4.06% N, 1.04% P, and 1.54% K. Diouf (2020) found that madre de cacao is a nitrogen-fixing tree with the potential to restore and maintain soil fertility, while Escalada (2002) and Javier (2019) found that ipil-ipil leaves as fertilizer enhance the soil properties and increase production in root crops. The use of ipil-ipil leaves as an organic fertilizer has been shown to effectively substitute for inorganic soil-based fertilizers in paddy rice production (Harahap, et al., 2022).

Overall, the use of fermented leguminous plant leaves (FLPL) as a fertilizer has been found to have numerous positive impacts on the growth, yield, and soil health of crops, including rice, maize, soybean, and vegetables (Kim et al., 2019; Li et al., 2020; Zhang et al., 2018; Ji et al., 2019; Chen et al., 2018; Wang et al., 2016). The FLPL is a low-cost and locally available fertilizer source, which can benefit small-scale farmers by reducing their costs and increasing their income (Setyaningsih et al., 2017). The nitrogen, phosphorus, and potassium content of FLPL has been found to vary based on the species and conditions under which they were produced, with some species, such as madre de cacao and ipil-ipil, being effective substitutes for synthetic fertilizers in rice production (Diouf, 2020; Naher et al., 2020; Winarni et al. 2016). The use of FLPL as a fertilizer also has the potential to reduce greenhouse gas emissions and improve soil fertility (Zhang et al., 2018).

The main aim of this study was to assess the feasibility of using fermented leguminous plant leaves as a fertilizer source in rice production, with a focus on determining the optimal type of fermented leguminous leaves and examining the economic benefits that small-scale farmers could potentially attain through their adoption. Using fermented leguminous plant leaves (FLPL) as a substitute for synthetic fertilizers in growing rice, had various benefits for science and society. From a scientific perspective, the research contributed to the agricultural literature by examining the effectiveness of FLPL, especially from madre de cacao, and how they affected the development of crops and the quality of the soil. The results also guided how to apply organic fertilizers in the best way, leading to more productive and eco-friendly farming methods. The research supported the idea of sustainable agriculture by addressing the issue of soil degradation caused by chemical fertilizers. Socially, the research had economic advantages for farmers, as it showed that fermented leguminous plant leaves (FLPL) were cheap and easy to obtain, reducing the financial burden on small-scale farmers.

METHODS

Research Design

The present study utilized a Randomized Complete Block Design (RCBD) to investigate the effects of various treatments on rice production. The experiment consisted of 12 experimental units, each measuring 30.915 square meters, with a total area of 464.69 square meters. The study consisted of four treatments, each replicated three times, including the application of synthetic fertilizers (T14 and urea), fermented acacia *(Samanea saman)* leaves, fermented ipil-ipil *(Leucaena leucocephala)*, and fermented madre de cacao (*Gliricidia sepium*). The RCBD method was employed to control extraneous variables and account for their effects on the results.

Treatment Preparation and Application

The treatments were prepared through the fermentation of ipil-ipil, acacia, and madre de cacao leaves, performed in one of the agricultural buildings of the DEBESMSCAT-Cawayan Campus. The same amount of each treatment was applied to each replication. The process involved the collection of plant material, cutting and weighing, mixing with molasses, packing, and allowing to ferment for 7 days, separating the liquid from the solid, and storing the fermented plant juice (FPJ). Treatment A was applied using T14 and urea in recommended doses, while Treatments B, C, and D consisted of 10.3 kg of fermented acacia leaves (4.06% N, 1.04% P, 1.54% K), ipil-ipil (4.3% N, 0.4% P, 2.7% K), and madre de cacao (3.8% N, 1.8% P, 2.8% K) per treatment replication, respectively. The treatments were applied three times per week (Monday, Wednesday, and Friday) until the rice reached the dough stage or three months after transplanting, with an application rate of 286 grams per treatment. The control treatment was administered with T14 two weeks after transplanting and urea 33 days after transplanting, with application rates of 1.3 kg for T14 and 200 grams for urea (14% N, 14% P, 14% K).

Data Collection and Statistical Analysis

The data was collected two weeks after transplanting and then at 28, 42, 63, 77, and 91 days after transplanting. The recorded data included initial plant height, the initial number of tillers, average plant height, the average number of tillers, number of grains per panicle, yield per treatment, yield per hectare, the average number of grains per treatment, average yield per treatment, average yield per hectare, and cost and return analysis. The statistical model used was the Analysis of Variance (ANOVA) with the RCBD as the experimental design. The sample size was determined using Sloven's formula. If the results of the ANOVA were significant, the Least Significant Difference (LSD) test was used to determine the significance of the results and to identify which treatments were significantly different from each other.

RESULTS AND DISCUSSION

Average Plant Height of Rice

The data presented in Table 1 reflect the average height of plants in centimeters, which have been subjected to different treatments with fermented leguminous leaves. The treatments are comprised of the control group, which utilized synthetic fertilizers, and three additional groups, which utilized fermented leaves of the Acacia, Ipil-Ipil, and Madre de cacao plants. It should be noted that the values in the table are presented with different letters (a, b) to indicate significant differences between the treatments. In this study, it appears that the height of the plants from the control group (synthetics) is significantly different ($P>0.05$) from the height of the plants in the three groups that received fermented leguminous leaves.

The results suggest that using acacia and madre de cacao leaves as organic fertilizers in rice production was quite effective in terms of increasing plant height. Plant height is an important aspect of a plant's ecological strategy as it is strongly related to life span, seed mass, and time to maturity, and is a major determinant of a species' ability to compete for light (David, 2019). The higher plant height found in the rice grown with acacia leaves during the 42 DAT and 71 DAT in the rice grown with madre de cacao leaves during the 71 DAT is likely due to the higher phosphorus (P) content of these two fermented leguminous leaves. Acacia leaves have a phosphorus content of 0.30% (Akkaeseng, 2020) and madre de cacao leaves have a phosphorus content of 1.8% (Natividad, 2011), while ipil-ipil leaves have a phosphorus content of only 0.4% (Paul et al., 2015). These two fermented leguminous leaves have greater capabilities to increase plant height compared to the ipil-ipil leaves.

Although the acacia leaves increased plant height during the two data collections and its number of heights was similar to the other fermented leguminous leaves, madre de cacao leaves still showed higher plant height than the other leguminous leaves after the last data collection. This may be due to the higher phosphorus (P) content of madre de cacao leaves, which is one of the essential nutrients for plant growth (Aleixo et al., 2019). This result is supported by the study of Rabena (2011), which showed that the height and root length of plants significantly increased when fertilized with madre de cacao fertilizer. It also helped improve soil productivity and fertility. Therefore, the use of madre de cacao leaves as organic fertilizer in rice production for more than three months should be considered to help increase plant height and overall plant growth.

Table 1. Average plant height applied with different leguminous fermented leaves (cm).

Treatments	Collection Period			
	28 days	42 days	63 days	71 days
Control (Synthetics)	47.13 [a]	64.35 [a]	97.04 [a]	106.03 [a]
Acacia Leaves	43.00 [b]	61.31 [a]	89.01 [b]	97.47 [a]
Ipil-Ipil Leaves	43.05 [b]	60.63 [a]	90.48 [b]	97.43 [a]
Madre de cacao	42.99 [b]	60.21 [a]	90.11 [b]	97.75 [a]

[a, b] Means in columns with the same letters are not significantly different at ($P>0.05$)

This study contributed to the growing body of literature on the use of fermented leguminous leaves as a fertilizer in agriculture. The results suggest that while fermented leguminous leaves can provide essential nutrients to crops and improve soil health, they may not have the same fertilizing effects as synthetic fertilizers (Ampong-Nyarko, K., & Oteng-Frimpong, R. (2015).

Average Tillers of Rice

The study's results presented in Table 2 demonstrate the average number of tillers produced by each treatment. The findings indicate that there were no significant differences (P<0.05) between the treatments in terms of the number of tillers produced. This information may be of interest to farmers who are concerned about the quality of the soil in which their rice is grown, as the use of synthetic fertilizer is only temporarily effective and requires re-applications. Conversely, the use of organic fertilizer promotes healthy soil and allows the plants to absorb nutrients most beneficially. This knowledge can help farmers understand the benefits of using organic fertilizer.

Table 2. Number of tillers of the plants applied with different fermented leguminous leaves (pcs)

Treatments	Collection Period		
	14 days	28 days	42 days
Control (Synthetics)	4.07 [a]	11.59 [a]	16.87 [a]
Acacia Leaves	3.60 [a]	8.92 [a]	13.65 [a]
Ipil-Ipil Leaves	3.60 [a]	9.88 [a]	13.16 [a]
Madre de cacao	3.80 [a]	10.41[a]	14.08 [a]

[a] Means in column with the same letters are not significantly different at (P<0.05)

At 28 days, the control group (synthetics) had an average of 11.59 tillers, while the groups that received fermented leguminous leaves had an average of 8.92-10.41 tillers. This difference in tiller number between the control group and the groups that received fermented leguminous leaves may be due to a variety of factors, including the composition and quantity of essential nutrients supplied by the fertilizers, the efficiency of plant nutrient uptake, and the influence of environmental factors such as temperature and soil type. The results show that rice plants treated with madre de cacao leaves produced a great number of tillers at 14, 28, and 42 days after transplanting. This increase in tillers was likely due to the nutrient content of the leguminous leaves, as phosphorus promotes plant division, root growth, and disease resistance, while potassium promotes growth and increases resistance (Wilson, 2020). Among the fermented leguminous leaves studied, Madre de cacao was found to produce a greater number of tillers. This is consistent with the observations of Villegas (2010), who noted that successful farmers in the area frequently use kakawate leaves in their rice farming. Therefore, the use of madre de cacao (kakawate) in rice production should be considered, though further research is necessary to determine the appropriate level of application and to fully assess its effectiveness.

Average Weight of Rice Grains on Wet and Dry Basis

Table 3 and Table 4 present the results of a study examining the effect of different leguminous fermented leaves on the weight of rice grains. The treatments evaluated included the use of a control (synthetics), Acacia leaves, Ipil-Ipil leaves, and Madre de cacao leaves as fertilizers. The results were presented in two forms: the average weight of rice grains per treatment in kilograms (Table 3) and the average weight of rice grains per hectare in tons (Table 4).

The table showed the weight of rice grains in kilograms for each treatment on a wet basis and a dry basis. The wet basis referred to the weight of the grains when they were harvested, while the dry basis referred to the weight of the grains after they were dried. The table also showed the statistical analysis of the data, using the letter a to indicate the significance level of the differences among the treatments. The letter a meant that there was no significant difference among the treatments at the 5% probability level (P<0.05).

Table 3. The average weight of rice grains per treatment applied with different leguminous fermented leaves on a wet and dry basis (kg)

Treatments	Grains (kg)	
	Wet basis per treatment	Dry weight per treatment
Control (Synthetics)	17.50 [a]	15.17 [a]
Acacia Leaves	13.80 [a]	12.25 [a]
Ipil-Ipil Leaves	12.67 [a]	11.17 [a]
Madre de cacao	14.27 [a]	12.67 [a]

[a] Means in column with the same letters are not significantly different at (P<0.05)

The table indicated that the control treatment (synthetics) had the highest average weight of rice grains on both wet and dry basis, followed by the acacia leaves treatment, the madre de cacao treatment, and the ipil-ipil leaves treatment. However, the differences among the treatments were not statistically significant, meaning that they could be due to chance or random variation. Therefore, the table suggested that the use of leguminous fermented leaves as organic fertilizer did not affect the yield of rice grains significantly compared to the use of synthetic fertilizers. This could be because the leguminous fermented leaves did not provide enough nutrients or did not match the nutrient requirements of the rice plants. Alternatively, it could be because the soil conditions or other environmental factors were not favorable for the growth of rice plants.

Table 4 showed that the results in terms of the average weight of rice grains per hectare were similar to those in Table 3, with the control treatment (synthetics) still having the highest average weight of rice grains per hectare on both wet and dry basis.

Table 4. The average weight of rice grains applied with different leguminous fermented leaves on a wet and dry basis (tons/ha)

Treatments	Grains (tons)	
	Wet basis per hectare	Dry weight per treatment
Control (Synthetics)	5.69 [a]	4.91 [a]
Acacia Leaves	4.40 [a]	4.08 [a]
Ipil-Ipil Leaves	4.10 [a]	3.61 [a]
Madre de cacao	4.65 [a]	4.22 [a]

[a] Means in column with the same letters are not significantly different at ($P<0.05$)

These results suggested that the use of different leguminous fermented leaves as a fertilizer has no significant impact on the weight of rice grains. Further studies are needed to determine the long-term effects of leguminous fermented leaves on rice production and to compare the cost-effectiveness of using leguminous fermented leaves as a fertilizer compared to synthetic fertilizers. In conclusion, the use of leguminous fermented leaves as a fertilizer has a positive impact on the weight of rice grains. This information could be used to improve the sustainability and efficiency of rice production systems by incorporating leguminous fermented leaves as a fertilizer.

Cost and Return Analysis

Table 5 illustrates the average net income per hectare of rice for different leguminous fermented leaves. It can be observed that the control treatment, which was treated with synthetic fertilizers, produced the highest net income. These results indicate that while the control treatment produced the highest net income, the use of leguminous fermented leaves as fertilizers still produced a considerable amount of income, although lower than the control treatment.

This study supports previous research that showed the use of organic fertilizers, such as leguminous fermented leaves, can still produce an acceptable yield and income compared to the use of synthetic fertilizers (Kundu, 2009; Islam et al., 2013). This highlights the importance of using organic fertilizers to promote sustainable agriculture and reduce the dependence on synthetic fertilizers that can cause environmental problems.

Table 5. Average net income of rice applied with different leguminous fermented leaves (Php/ha)

Treatments	Net Income (Php/ha)
Control (Synthetics)	130,357.43 [a]
Acacia Leaves	116,988.52 [a]
Ipil-Ipil Leaves	106,744.30 [a]
Madre de cacao	121,300.34 [a]

[a] Means in column with the same letters are not significantly different at ($P<0.05$)

In conclusion, the results of this study demonstrate the potential of using leguminous fermented leaves as an alternative to synthetic fertilizers in rice production. This can provide farmers with a more cost-effective and environmentally friendly option for improving their yield and net income. Further research should be conducted to confirm the findings and explore other leguminous fermented leaves for their potential in rice production.

CONCLUSION

The results showed that the control group that received synthetic fertilizers produced the tallest plants, with significant differences ($P>0.05$) from the three groups that received fermented leguminous leaves. Among the fermented leguminous leaves, the plants that received fermented Madre de cacao leaves showed the highest plant height, which may be due to their higher phosphorus content. In terms of the number of tillers, the results showed no significant differences between the treatments, suggesting that fermented leguminous leaves can provide the necessary nutrients to crops in a way that is beneficial to their growth. The net income using fermented leguminous plant leaves is comparable to synthetics. Therefore, farmers can use the FLPL as a fertilizer in their rice production process while maintaining a sustainable and environmentally friendly approach.

Further research is needed to explore the impact of fermented leguminous leaves on rice production and other crops, as well as the best methods for preparing and applying these fertilizers.

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